The Central kpc of Starbursts and AGN
ASP Conference Series, Vol. xxx, 2001
J. H. Knapen, J. E. Beckman, I. Shlosman, and T. J. Mahoney

Structural properties of spiral galaxies with and without an AGN: morphology and kinematics

Isabel Márquez

Instituto de Astrofísica de Andalucía (CSIC), Apdo. 3004, 18080 Granada (Spain)

DEGAS Consortium

Abstract. The analysis of a sample of 30 isolated spiral galaxies with and without an AGN results in active and control galaxies having similar bulge and disk properties (since both samples are selected to match in morphological and bar classification, they have similar bar percentages). Secondary bars seem also to be indistinguishable. The central kinematics (both stellar and gas) are also studied in order to put some constraints on the processes required to fuel AGNs. Together with previous results, this points to AGNs being an episode of the life of galaxies, providing that the fuel is available and the accumulation mechanisms are at work.

1. Introduction

AGN activity in galaxies is a highly energetic phenomenon that takes place in a very small spatial extension located at the very center of some galaxies, and that results to be more frequent in the Early Universe. The connection between AGN activity and gravitational interaction was already claimed in the 70's and is still nowadays a matter of debate. In any case, galaxies with AGNs are found in interacting systems, from nearby Seyferts to quasars. Gravitational interaction is also assumed to increase the percentage of systems hosting starburst activity. AGN and violent star formation (SF) activity very often appear simultaneously, but the physical connection between both phenomena still have to be elucidated.

2. AGNs and bars

Interestingly, the morphology of the host galaxies seems to play a role in determining what galaxies are susceptible of harboring an AGN, in the sense that AGNs more probably reside in early type spirals (Balick & Heckman 1982; Márquez & Moles 1994; Moles, Márquez & Pérez 1995; Ho et al. 1997; Knapen et al. 2000). This is specially important for active galaxies that can be considered as isolated objects, and therefore the effect of the interaction cannot be invoked to explain the presence of AGN activity; the presence of a bar appears as a natural explanation, since it can produce an effective loss of angular momentum and therefore be the first step in feeding the central parts with fresh gas coming from the disk (Simkim, Su & Schwarz 1980). However, the general result

is that the bar percentage is similar for active and non-active galaxies (Moles et al. 1995; McLeod &Rieke 1995; Ho et al. 1997; Mulchaey & Regan 1997). Hunt & Malkan (1999) reach the same conclusion, and also claim that the incidence of outer and inner rings seem to be different for the various activity classes (a result that they explain as an evolutionary sequence from LINERS, which have more inner rings to Seyferts which have more outer rings). Only Knapen et al. (2000) obtain a slightly higher fraction of barred galaxies among Seyferts. Note that when only isolated galaxies are considered, barred and unbarred galaxies are equally found among active and non-active galaxies (see Márquez et al. 2000).

An additional step is required to transport the material eventually feeding the AGN close enough to the center. With this respect, nested bars supply such a mechanism, nuclear bars producing the same effect as large scale ones, but at smaller distances to the center (Norman & Silk 1983; Shlosman et al. 1989; Wozniak et al. 1995; Friedli et al. 1996). Following this reasoning, nuclear bars have been looked for, but only found for much fewer cases than expected if they have to be directly connected with the presence of nuclear activity (Regan & Mulchaey 1999; Martini & Pogee 1999; Márquez et al. 1999, 2000); even if the percentage of nuclear bars could increase when the identification of a nuclear bar is properly done, other mechanisms that can also explain the funneling to the center seem to occur, as nuclear spirals or nuclear warps.

3. The DEGAS' contribution

The DEGAS (Dynamics and nuclear Engine of GAlaxies of Spiral type) project is aimed at studying the connection between the galactic structure of spiral galaxies and their AGN activity. We have only selected isolated objects in order to avoid any bias from the inclusion of interacting objects, the central properties of which could have been modified by interactions. The active galaxies have been chosen with the following criteria: (a) Seyfert 1 or 2 from the Véron-Cetty & Véron (1993) catalogue; (b) with morphological information in the RC3 Catalogue; (c) isolated, in the sense of not having a companion within 0.4 Mpc (H_0=75 km/s/Mpc) and cz<500 km/s, or companions catalogued by Nilson without known redshift; (d) nearby, cz<6000 km/s; and (e) intermediate inclination (30 to 65°). The non active sample galaxies have been selected among spirals verifying the same conditions (b), (c), (d) and (e), and with morphologies (given by the complete de Vaucouleurs coding, not just the Hubble type, so they also match in bar types) similar to those of the active spirals. We already stressed that these non active galaxies are well suited to be used as a control sample. Based on previous work (Moles et al. 1995), we search for detailed morphological and kinematical differences between active and non active galaxies of similar global morphology. We particularly pay attention to those that could facilitate the transport of gas towards the very central regions and the nucleus. For this purpose, we are obtaining optical and near-infrared images and long slit spectroscopy with the best possible spatial resolution.

3.1. Near-infrared morphology

Infrared imaging is particularly important because it allows to trace the old stellar population, and to separate the various components (the bulge, disk,

bar(s) and spiral arms) with the smallest contribution of the active nucleus and less contamination by dust absorption. We have analysed the morphological and photometric properties of a sample of isolated spirals with (18) and without (11) an active nucleus, based on J and K' imaging (Márquez et al. 1999, 2000).

The mean resolution of our images is about 1 arcsecond, corresponding to a physical resolution between 100 and 300 parsecs for the closest and the more distant galaxy respectively. This resolution implies that we are able to map the region where the dynamical resonances are expected to occur (see for instance Pérez et al. 2000) and is therefore well suited for our purposes.

We have found that four (one) active (control) galaxies previously classified as non-barred turn out to have bars when observed in the near-infrared. One of these four galaxies (UGC 1395) also harbours a secondary bar. For 15 (9 active, 6 control) out of 24 (14 active, 10 control) of the optically classified barred galaxies (SB or SX) we find that a secondary bar (or a disk, a lense or an elongated ring) is present. Our study shows that both sets of galaxies are similar in their global properties: they define the same Kormendy relation, their disk components share the same properties, the bulge and disk scale lengths are correlated in a similar way, bar strengths and lengths are similar for primary bars. Our results therefore indicate that hosts of isolated Seyfert galaxies have bulge and disk properties comparable to those of isolated non active spirals. Central colors (the innermost 200 pc) of active galaxies are redder than the centers of non active spirals, most probably due to AGN light being re-emitted by the hot dust and/or due to circumnuclear SF, through the contribution of giants/supergiants.

Central to our analysis is the study of the possible connection between bars and similar non axisymmetric structures with the nuclear fuelling. We notice that only one of the Seyfert galaxies in our sample, namely ESO 139-12, does not present a primary bar. But bars are equally present in active and control objects. The same applies to secondary bars. Not all the active galaxies we have observed have them, and some control galaxies also present such central structures. Secondary central elongations (associated with secondary bars, lenses, rings or disks) may be somewhat different, but this result should be confirmed with larger samples. We note that numerical models indicate that such secondary bars are not strictly necessary to feed the central engine when a primary bar is present. Our results show that down to scales of 100-300 pc, there are no evident differences between active and non active spiral galaxies. The details of the data description and analysis are given in Márquez et al. (1999, 2000).

3.2. Gas and stellar kinematics: the case of NGC 6951

Nuclear activity needs to be fueled with a supply of gas, the reservoir of which can be provided by the disk of spiral galaxies. The existence of gas to fuel the circumnuclear activity is necessary but not sufficient (e.g., Moles et al. 1995; Mulchaey & Regan 1997). The right dynamical and physical conditions must exist for this gas to be used effectively in either infalling on to the nucleus itself and feeding the AGN or nuclear starburst, or collapsing by self-gravity in the circumnuclear region in the form of intense SF. To understand what are the conditions and mechanisms for the onset of nuclear activity in spiral galax-

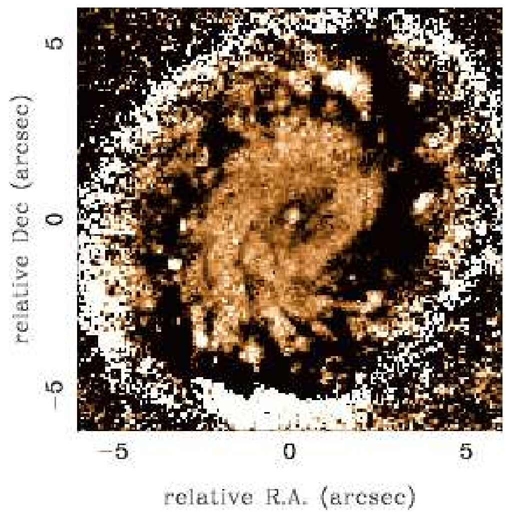

Figure 1. J-H colour image of the circumnuclear region of NGC 6951 (HST+NICMOS, spatial scale = 0.075″/px) where the nuclear spiral is clearly seen.

ies, a detailed characterisation of morphological and kinematical components in galaxies of different morphology and activity level is needed. We have already proceeded with such an analysis for the active SAB(rs)bc galaxy NGC 6951, by means of broad band B'IJK images and high resolution high dispersion longslit spectroscopy, together with archival HST WFPC2 V and NICMOS2 J and H images (Pérez et al. 2000). We found that:

a) There is little ongoing SF inside the bar dominated region of the galaxy, except for the circumnuclear ring at 5″radius. This SF occurs in two modes, in bursts and continuously, along the ring and inwards towards the nucleus. The equivalent width of the CaII triplet absorption lines show that in the metal rich central region of this galaxy, within 5″radius, the continuum light is dominated by a population of red supergiant stars, while outside the circumnuclear ring the stellar population is that of giants.

b) We suggest that the gaseous and stellar kinematics along the three slit position angles can be interpreted as the existence of a hierachy of disks within disks, with dynamics decoupled at the two ILRs, that we find to be located at 180 pc and at 1100 pc. This would be supported by the nuclear spiral structure seen in the high resolution HST images (see Fig. 1). Outside the iILR the stellar CaT velocity profile can be partly resolved into two different components that seem to be associated with the bar and a disk (see Fig. 2).

c) We discuss the possibility that the kinematic component inside the iILR could be due to a nuclear disk, as in the disk within disk scenario suggested above, or to a nuclear outflow produced by the combined effects of SN and SN remnants. Several clues indicate that this is a dynamically old system: (i) there is little SF ongoing inside the bar dominated part of the galaxy (except for the circumnuclear ring), (ii) the relative amount of molecular to total mass within the inner 6 arcsec radius is very large $\approx 25\%$, and (iii) the geometry of the circumnuclear ring leading at a position angle greater than 90° from the

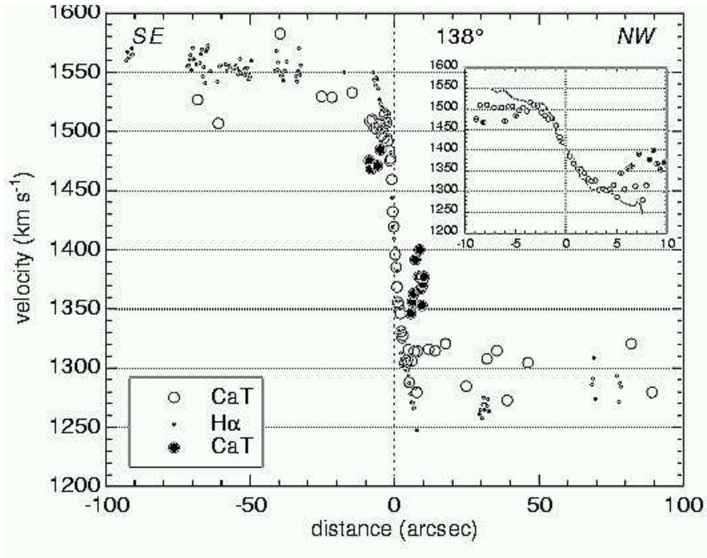

Figure 2. Stellar (circles) and ionized gas (dots) velocity curve along the major axis of NGC 6951. In the central region the CaT absorption lines are resolved in two components (filled and open circles).

stellar bar. It is thus possible that a nuclear bar has existed in NGC 6951 that drove the gas towards the nucleus, as in the bars within bars scenario, but that this bar has already dissolved due to the accumulation of the gas within the circumnuclear region (Pérez et al. 2000).

A detailed kinematical and morphological analysis for a number of galaxies in our sample is in progress. Intermediate resolution data for the gas kinematics have already been obtained for the great majority of the galaxies. High spatial and spectral resolution spectroscopy for the gas and stars have been obtained for about ten galaxies and will be analysed as for NGC 6951.

4. Conclusions and further considerations

We have shown that isolated spiral galaxies with or without an AGN are equivalent in the sense of hosting similar large scale components (bulges, disks, bars). To analyse the processes taking place in the central regions, both detailed morphology and high resolution spectroscopy of gas and stars are needed, together with detailed models for the interpretation, as it is the case for example for the double stellar component in NGC 6951.

Bars are dynamically active, so it is relevant to consider that different time scales are involved in the processes of bar creation and evolution, SF and AGN activity, and hence the observable connection between bars and AGNs may be more complex. With respect to the availability of fuel, it has been found that CO is more concentrated in barred galaxies, with no difference for active and non-active ones (Sakamoto 1999). Similar rotation curves (Sofue & Rubin 2001) and environments have also been reported for active and non-active galaxies.

The masses of the central compact objects (black holes) seem to be comparable (Ferrarese & Merritt 2000; McLure & Dunlop 2000; Laor 2001), with M_{bh}/M_{bulge} $\approx$ 0.005%, with a maximum of $\approx$ 0.025% (we stress that numerical simulations show that the bar is destroyed when the central mass is about 1-10% the total mass – see Combes 2001–, so this could explain the limit in BH masses). Therefore, if galaxies hosting AGN have no properties differing from those with of galaxies without an AGN, it could be that the AGN is an episode of the life of a galaxy, providing that the fuel is available and the accumulation mechanisms are at work. Such accumulations would also help to trigger SF processes (competitive or not) that seem to coexist with AGN activity.

References

Balick B. & Heckman T.M. 1982, ARA&A, 20, 431

Combes F. 2001, ASP Conf. Ser., Vol. 230, 213

Ferrarese L. & Merritt D. 2000, ApJ, 539, L9

Friedli D., Wozniak H., Martinet L. & Bratschi P., 1996, A&AS, 118, 461

Ho L.C., Filippenko A.V. & Sargent L.W. 1997, ApJ, 487, 591

Hunt L.K. & Malkan M.A. 1999, ApJ, 516, 660

Knapen J.H., Shlosman I. & Peletier R.F. 2000, ApJ, 529, 93

Laor A. 2001, ApJ, 553, 677

Márquez I. & Moles M. 1994, AJ, 108, 90

Márquez I., Durret F., González Delgado R.M. et al. 1999, A&AS, 140,1

Márquez I., Durret F., Masegosa, J., et al. 2000, A&A, 360, 431

Martini P. & Pogge R.W. 1999, AJ, 118, 2646

McLeod K.K. & Rieke G.H. 1995, ApJ, 441, 96

McLure, R.J. & Dunlop, J.S. 2000, MNRAS (submitted) (astro-ph/0009406)

Moles M., Márquez I. & Pérez E. 1995, ApJ, 438, 604

Mulchaey J.S. & Regan M.W. 1997, ApJL, 482, L135

Norman, C. & Silk, J. 1983, ApJ, 266, 502

Pérez E., Márquez I., Marrero I. et al. 2000, A&A, 353, 893

Regan M.W. & Mulchaey J.S. 1999, AJ, 117, 2676

Sakamoto, K. et al. 1999, ApJ, 525, 691

Shlosman I., Frank J. & Begelman, M. 1989, Nature, 338, 45

Simkin S.M., Su H.J. & Schwarz M.P. 1980, ApJ, 237, 404

Sofue, Y. & Rubin, V. 2001, ARA&A (submitted) (astro-ph/0010594)

Véron-Cetty M.P. & Véron P. 1993, "A catalogue of Quasars and Active Nuclei", 6th Edition, ESO Scientific Report #13

Wozniak H., Friedli D., Martinet L. et al. 1995, A&AS, 111, 115